Health Service Sites Access Analysis Using Internet GIS

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Abstract

Health service sites access assessment is critical for patients looking to get timely and proper service. Also, access analysis results can be helpful when recruiting health care providers in underserved areas, or when referring patients to nearby practitioners. Health service sites access assessment is a typical spatial analysis, which can be greatly improved by using a geographic information system (GIS). However, given the hardware and software requirements, a GIS package itself is not always easily accessible to the public. In addition, lack of adequate training acts as a major barrier blocking ordinary people from exploring the power of GIS. Thus, we are in critical need of a bridge to bring GIS to ordinary people who need to solve spatial analysis problems such as health service sites access analysis. The development of distributed technology today makes it possible for data and software service providers to offer access to their services to anyone connected to the Internet, and for users to benefit from being able to share resources regardless of their physical location. Given the popular access to and general familiarity with the World Wide Web, the Internet could be an ideal vehicle to carry both GIS functions and health service information to people who need them. That will definitely enhance health services' capability for improving people's quality of life. In addition to proposing that health service sites access analysis be available on the Internet, this paper also discusses three architectures and general models using Internet GIS for performing the access analysis.

Keywords: access analysis, common gateway interface (CGI), common object request broker architecture (CORBA), Internet GIS, public health service

Introduction

One of the most widely agreed-upon statements on the role of public health is that it is an essential service of public health to ensure that all members of the community have access to health services (1). Access to a health service site is critical to the increased efficiency and effectiveness of health care delivery. It is an important issue for both service consumer and service provider. Health service consumers have the need to identify or be referred to the most suitable, as well as nearest, service site. Thus, having access to and being able to perform analysis on information about health service sites is essential for consumers if they are to access health services more conveniently and efficiently. For health service providers, their operations are highly related to their service capabilities and market shares. Providers need to define their service area and population. They need to identify the underserved and/or high-risk populations in order to give full play to their services. Hence, information and analysis are necessary

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for health providers to get full and accurate knowledge about access to their services for the public. They also need to process the related information to stipulate and evaluate a development strategy for their services. Furthermore, from the standpoint of public health agencies and government, access assessment is a basic method for evaluating and ensuring universal access to health services. The analysis is essential for making decisions on health service recruiting, planning, and other development strategies and policies.

Obviously, the ability to access and process information about health services is the first and foremost step for all parties to improve access analysis and delivery of health services. Actually, many organizations and researchers have already taken steps to implement new information technology in the health care industry. Recent efforts and practices in building and testing both a community care network (CCN) and community health information network (CHIN) are good examples. Both networks have adopted the idea of improving information availability and exchange. A CCN, which emphasizes information exchange and broad collaboration, includes as its vision "making the system more understandable and user-friendly for patients and enrollees" and "continually improving the continuity and quality of health care services" (2). And a CHIN, although still in the innovation stage, has agreement on minimum elements including that "computer-based information systems and networks form the base technologies of CHIN," and "the major domain of CHIN data transferred is health and the provision of health services" (3). In the mean time, many public health agencies take advantage of Internet technology and post certain information (e.g., locations, contact information) about public health services on their Web pages to provide better service for their customers. However, the majority of these existing efforts to improve information availability are of a traditional and rudimentary status—they basically provide text information with little clue about actual spatial accessibility, and information is general rather than locally specific.

Access assessment is a typical spatial analysis problem that can be easily handled by GIS technology. In addition, GIS' usual products of a map and/or report are very easy for GIS laymen to understand and communicate. Nevertheless, GIS, being a technology having special hardware, software, and personnel training requirements, is not readily available to the public. We need to find a way to perform GIS functions for access analysis at a simpler level or relieve the special requirements that block the general public from using the technology. Fortunately, the recent development of information technology in general and distributed computing and Internet technology in specific make it possible for ordinary people to use GIS for health service access analysis while avoiding the almost formidable expenses in terms of both time and money.

The rest of this paper will be devoted to exploring the potential of modern information technology for improving the general public's ability to access and process health service information. Based on the discussion about the potential of distributed computing technology and Internet GIS, three architectures applying these technologies to processing health service information are proposed. The three architectures are a server-side application, a client-side application, and an Internet-savvy application. The purpose and pros and cons of each of these approaches are discussed. Finally, the general implications of these development models for the future of the public health industry are addressed.

Data for Health Service Access Analysis

"Access to health services" refers to how easy it is for consumers to get the necessary service and for providers to deliver their services. Usually, it is measured by the impact of geographical distance on the convergence of health service providers and consumers. Broadly speaking, though, access analysis also concerns the impact of factors related to the consumer's as well as the provider's social, economic, cultural, and even language situation. For example, a non-English speaking patient may prefer to travel longer just to get service from a certain site where the patient feels it is easier to communicate. Hence, data needed for a useful and effective access analysis is far beyond just a simple map from which physical distance between locations can be measured easily. Social, economic, demographic, and environmental data are all necessary.

Generally speaking, the data for health service access analysis have the following properties: First, data volume and categories are large and data are usually generated by various parties. Some data (e.g., census data and TIGER street maps) are more general and easy to obtain; others (e.g., location information about service sites) could be very specific both geographically and thematically and need to be created from scratch. Second, related data are maintained and updated separately and independently by different parties. Consequently, data concurrency and integrity must be checked carefully. Because of the spatial nature of access analysis and the large size of the databases, GIS is undoubtedly the most powerful tool.

GIS is far from reaching its full potential in health service access analysis. Even though GIS is the best tool for maintaining and analyzing large spatial databases, difficulties in physically obtaining, owning, and maintaining all related data as well as a GIS package restrict GIS to the hands of selective researchers and health service professionals who have the resources and expertise. This does not excuse us, however, from attempting to use GIS technology to enhance the effectiveness and efficiency of our health service delivery. The hope lies in new information technologies—distributed computing and Internet GIS.

A New Vision of Distributed Computing Technology

Distributed computing technology is the technology that integrates a collection of distributed operating systems and/or distributed database systems by a communication subnet. The communication subnet may be a widely geographically dispersed collection of communication processors or a local area network. The emergence of distributed computing technology is significant for the development of information technology such as GIS. "It is now possible for parts of a database to be stored and maintained at different locations, for users to take advantage of economical or specialized processing at remote sites, for decision makers to collaborate across computer networks to make decisions, and for large archives to offer access to their data to anyone connected to the Internet" (4).

Distributed computing has certain advantages. First, costs are significantly lowered, while access to information technology is greatly improved. Multiple organizations and users can now share both expensive special processors and mutually desired datasets. Tremendous money, time, and personnel could be saved, and more people can access processor resources and databases. Second, geographical restrictions to accessing

resources and data are totally removed. Distributed computing technology makes it possible to remotely access both resources and data. It gives people more geographical flexibility. Finally, greater flexibility and reliability of a distributed system make facilities and data easier to share and maintain. All elements of the distributed system are connected to each other while relatively independent. Deleting, adding, updating, or even failure of a certain element does not affect the availability of others at all.

When combining distributed computing technology with GIS, we can envision the following benefits for our health service access analysis: First, spatial data generated by different parties could be easily integrated for certain applications; in this case, it would be health services access assessment. Database redundancy and computer facility waste from keeping multiple copies of data are minimized. Second, data maintenance is distributed and data are relatively easy to update. Updating "master copy" data will ensure that every user can get timely data all the time. Spatial analysis results of GIS are more reliable, valuable, and consistent across applications. Third, GIS hardware and software, although sophisticated, can be shared by geographically dispersed users. In sum, the development of distributed computing technology, by enabling the sharing of related data and GIS resources, makes it much easier for people to perform health service access analysis. It greatly reduces the requirements on the public in terms of GIS data, facilities, and experience. So, the problem now is, how do we combine traditional GIS with distributed computing technology?

Internet GIS Technology as a Valuable Direction

"Internet GIS is a network-centric GIS tool that uses the Internet as a primary means of providing access to the functionality (i.e., analysis tools, mapping capability) of GIS and to the spatial data and other data needed for various applications" (5). According to this definition, Internet GIS could be an ideal way to improve the public's assessment of health services access by enabling them to share data and GIS functions via Internet technology.

Although there has been basic research advocating the combining of GIS technology with the Internet (6), most of the development to date has been through the experimental development of both prototype and production services by different organizations. It is commonly acknowledged, however, that the Internet is a good vehicle, with the help of distributed computing technology, to empower more people with the capability to access and handle large spatial databases.

The Internet has certain characteristics that make it especially suitable as a means for combining distributed computing and GIS technology. First, the Internet (e.g., the World Wide Web) is very popular today and highly accessible to ordinary people. New content added to the Internet has good potential for being accessed and accepted by the general population. Next, the user-friendly aspect of the Internet and its browsers' capability for transferring and displaying text, graphics, and image files make the Internet a good medium for communication of spatial information and process results. Lastly, the Internet can provide interactive communication between users and data, and this is the foundation for the interactivity between Internet GIS users and spatial data. This characteristic of the Internet allows for the possibility of sending a dynamic map/image to a browser in addition to ordinary static ones.

Nevertheless, the World Wide Web and its hypertext markup language (HTML)

cannot directly recognize spatial analysis requests; neither can they handle spatial data in the way GIS software does. Therefore, in addition to a Web browser and Web server, special GIS tools need to be added in to understand and respond correctly to spatial data handling requests. Different solutions for adding GIS functions to build real Internet GIS result in different frameworks.

The first solution is purely distributed computing in technology and simple and consistent in logic. It is a server-side Internet GIS solution and is classified as a typical heavy-server and thin-client framework (Figure 1). The most important property of this

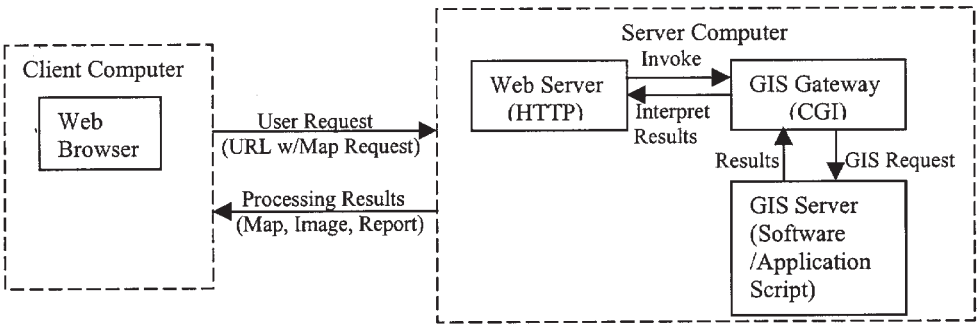

Figure 1 Framework of server-side Internet GIS.

framework is that GIS requests are always handled by the remote server(s). Common gateway interface (CGI) is widely used on the server's side to link Web server with GIS server. All parameters of GIS requests are interpreted by CGI for the GIS server to process; the results from the GIS server are interpreted and passed back to the Web server by CGI as well. In this framework, both spatial data and GIS resources are totally shared by multi-clients. The only task for the client machine (Web browser) is to receive a request from the user, send it to the server, accept processing results from a server, and display results. This solution is good because it could provide a whole set of complicated GIS functions to a user and could deal with a large database. Also, from the server's point of view, it is easy to maintain both database and GIS resources, and easy to control the access for different user groups. Nonetheless, it lacks flexibility and interactivity for the user. The user can only work with data in a limited way and receive static data processing results. Moreover, every request from the user, even though it could be quite simple, has to be sent back and forth through the Internet to the server, which causes high Internet traffic and a heavy workload for the server.

The second solution aims at giving the user more flexibility by doing GIS data processing and analysis on the client side. This client-side Internet GIS is classified as a light-server and thick-client framework (Figure 2). The hallmark of this solution is that GIS tools are located on the client's machine. The functions and powerfulness of GIS tools on the browser's side could be significantly different though, depending on the GIS package designed for the application. However, the user does not necessarily have his or her own GIS package and expertise. This framework supports the user's request for GIS tools from the server and the "installation" of the tools on the client's machine.

There are two general models of GIS tools for the client to request from the server: GIS plug-ins and GIS applets, both of which can efficiently add GIS functions to the

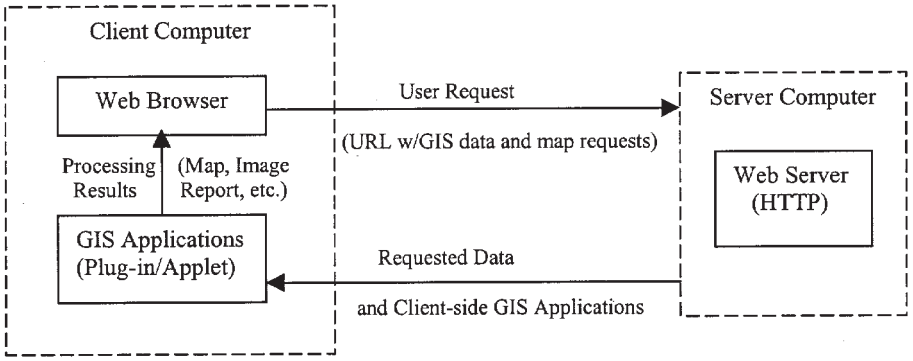

Figure 2 Framework of client-side Internet GIS.

client side. A GIS plug-in needs the client to download and install it as a normal program, which takes up not only time before the Internet GIS can be used but also permanent space on the client's machine. A GIS applet could be written in either Java or ActiveX. It could be designed to download automatically before the user issues a GIS request. An applet takes up space too, but the space will be released when the user leaves the Web site. Compared with server-side Internet GIS, the second solution provides the user with more flexibility and interactivity, because the user can process GIS data as he or she is using stand-alone GIS software. Because the GIS analysis is performed on the client side, not much Internet traffic is generated. Due to the requirement on client-side hardware resources, however, the framework is weak in handling large databases and performing complicated GIS functions.

In addition to the two above-described basic solutions, there are other frameworks, most of which are combinations of server-side and client-side solutions. Every solution has its own advantages and disadvantages, and thus is suitable for different situations. Many aspects of a GIS application, such as size of related spatial database, expected request frequency and data volume, the complexity of most-often-generated GIS queries, hardware capability available for general users, and even the maintenance of the server(s), can all influence the choice of Internet GIS solution.

Three Architectures for Health Service Access Assessment Internet GIS

It is clear now from previous discussion that data for health service access analysis are miscellaneous and huge, and usually generated and maintained by various parties. Also, health service access assessment is important for multiple groups, the three most important of which are health service consumers, health service providers, and public health agencies and organizations. With the assist of distributed computing technology, Internet GIS can be employed to integrate a variety of data and to empower people from different groups to process information. However, different user groups of the Internet GIS health service access application have different expectations and requirements. In order to provide all users with effective Internet GIS analysis power while keeping the application as efficient as possible and avoiding waste of resources, different development strategies should be implemented for different user purposes and analysis levels. The three Internet GIS architectures proposed here for these different

strategies are static access query and display, interactive access information query, and comprehensive and intelligent access analysis.

Static Access Query and Display

The static access query and display (SAQD) model is designed for the general population (health service consumers and patient referrers) to perform a simple and static query on access to health services. This application can perform such queries as location(s) of nearest health service site(s), route and directions to the site(s), and some other general information about the service of the site(s) (e.g., category of service(s), service capability and quality, contacting information). The query results will be a combination of map image and text. To enhance the display quality of the map, functions such as pan and zoom are also available for users. To give the user more flexibility, further development could include more features, such as allowing users to build more complicated and restricted queries according to their special requirements and concerns.

The functions and features of SAQD are designed based on the characteristics of potential users and their queries. This group of users and their usage of the Internet GIS have the following features:

- Queries are usually simple, and a static map plus text information can satisfy their general requests.
- Queries should be in relatively high volume, which is important when considering the amount of requests sent to the server.
- This application requires relatively quick response from the server.
- Users usually do not have access to a complicated GIS package; neither do they necessarily have access to terminals/client computers of high power.

Based on the above-mentioned features, this Internet GIS application is a typical thin-client one. The server does all the data integrating, analyzing, and map generating, while the client machine only accepts and delivers requests, receives results from the server(s), and displays the results (Figure 3). Although the server does most of the job, it does not necessarily result in heavy duties for the server, because the query is very simple and routine. The server does not perform sophisticated processing at all. Not-too-complicated scripts, an efficient search engine, plus well-organized databases could be specially packed together for this application. Actually, there are similar applications developed and used on the Internet. VISA ATM Locator is a good example (http://www.visa.com). The basic approaches are similar, although the static access

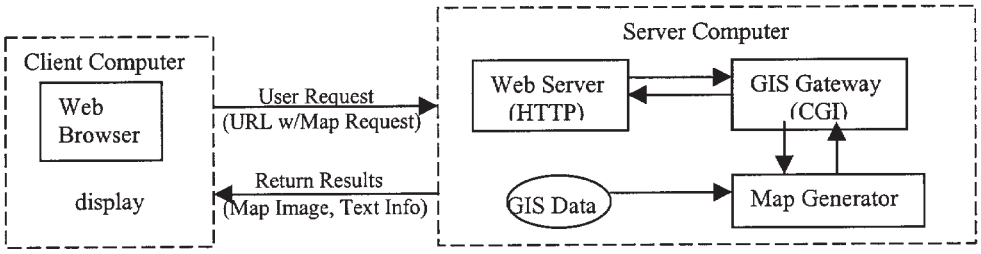

Figure 3 Architecture of static access query and display.

analysis Internet GIS for health service certainly contains more features, including pan and zoom buttons.

This approach has certain advantages. First, it does not require any special GIS or other resources on either client side or server side. Thus, it is easy to install. In addition, access to the application is almost ubiquitous, given the popular access to the Internet. Finally, server-side architecture makes it easy to maintain and update both data and a data analyzing, map generating package. The major drawback of this application is that it lacks the interactivity between the user and the spatial data. Also, the map that is transferred from server to client creates a relatively large volume of cyber traffic.

Interactive Access Information Query

The interactive access information query (IAIQ) Internet GIS application is built to satisfy the needs of relatively higher level queries. Major potential users are health service providers and other people who are concerned not only about the location of and route to health service sites but also about service area, population, and other socioeconomic attributes of a service area. Similar to the first group of Internet GIS users, this group also expects a relatively quick response to its requests. This group is somewhat smaller than the first one; hence, query volume should be relatively low. Also different from the first group, this group tends to generate higher level queries that request more data categories and relatively sophisticated data analyzing. Query format and content could be more interactive and complicated; dynamic maps, interactive queries, and even simple simulations may be required. Obviously, real GIS functions must be implemented. A higher level of Internet GIS service is required. IAIQ Internet GIS is the model able to satisfy these criteria. According to this architecture, maps and text information, as well as basic functions such as pan and zoom, will definitely be retained. New features such as identifying map features, interactively generating an object attribute report, turning on and off the display of multi-layers, and even performing a simple dynamic simulation, will be added in.

IAIQ is a typical client-side Internet GIS solution, conducting data analysis and map generating on the client's computer. Requests about health services, their service areas, and/or the basic situation of their major clients, and so on, are received by the client computer. Next, related data needed to process the requests as well as necessary GIS applications/scripts are passed back to the client computer from the server(s). Finally, GIS tools process related data on the client machine and the results are passed to the browser for display (Figure 4). The significant feature in this model is that the client machine gets both data and specially designed and packed GIS tools from the server. Flexibility of processing data using the GIS tools is guaranteed. The speed of dealing with further requests from the browser is relatively high.

As discussed earlier, there are two basic structures of the GIS tools: plug-in and Java/ActiveX applet. The preferred approach depends on the characteristics of the users. Compared with the first architecture of Internet GIS proposed, this architecture is supposed to serve the needs of people who are interested in analyzing health service access regularly, as well as users who are usually concerned about certain aspects of health service consistently. It is reasonable to assume that they have access to powerful computers and are willing to download and install the plug-in as a stable GIS tool kit

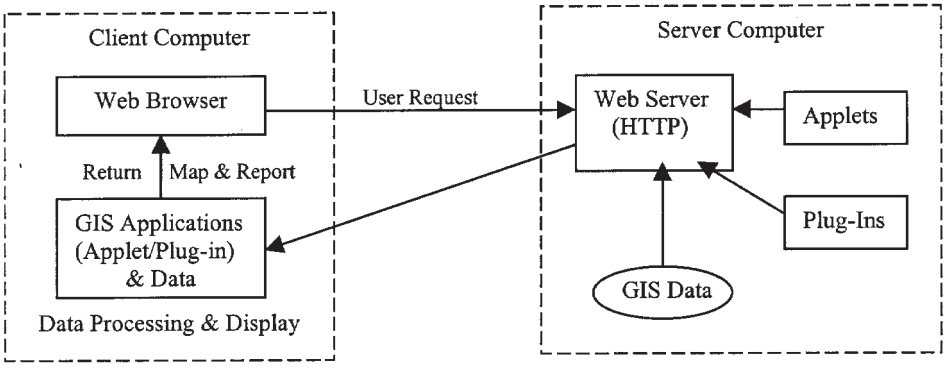

Figure 4 Architecture of interactive access information query.

to assist their analyses. As a matter of fact, plug-ins are usually more powerful than applets and more stable as well.

This approach is good for relatively high level GIS queries and interactive communication between users and data. Also, processing GIS requests on the client side is relatively quick and can avoid the need to send every request to and from the server. One disadvantage is that time is needed to download and install the GIS tool kit. Moreover, users need to receive timely information about the upgrade of the GIS tool kit, especially when a plug-in solution is adopted.

Comprehensive and Intelligent Access Analysis

A comprehensive and intelligent access analysis (CIAA) architecture of an Internet GIS application is on the highest level both functionally and technologically. Almost the whole set of GIS functions that can be found in normal GIS software is provided. A distributed computing technology that can handle real time data sharing is required, though it is actually not mature enough to date. The vision of this architecture is that elements of the Internet GIS, including clients, data providers, and GIS server(s), are distributed across the Internet while being able to communicate with each other and share data and resources in a timely manner. It is referred to as a "Net-savvy" GIS application by Plewe (7). The core point of this solution is the complete distribution of almost every element.

For a GIS analysis on health service access, the CIAA solution makes it possible for users to directly use census data from the Census Bureau, a street map from Etak, data about sites and services from public health service agencies and offices, and even newly released data about the most recent toxic substance leaking accidents. This supports health service access analysis on both the current situation and potential requirements. It can also enhance the evaluation of planning and development strategies and policies of health service systems through simulation of future scenarios. This is an architecture meeting the highest requirements of Internet GIS' function and power. It can satisfy the needs of health service administrator, planner, development policy stipulator and evaluator, and other specialists interested in evaluating the efficiency and effectiveness of a health service delivery system.

From a technical point of view, this approach is a severe heavy-client one (Figure 5). All the powerful GIS analysis is performed on the client side. The client software is a

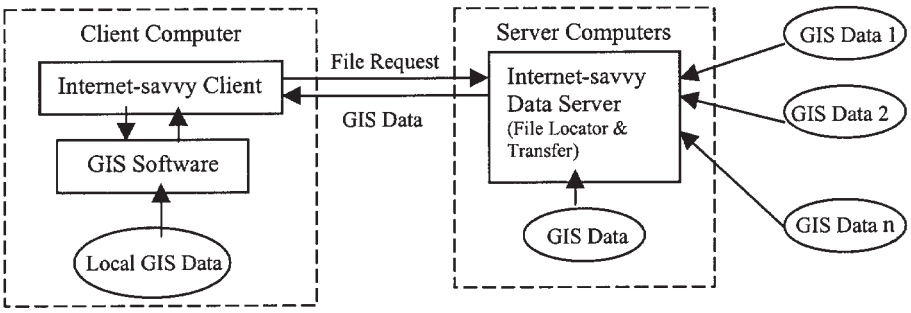

Figure 5 Architecture of comprehensive and intelligent access analysis.

standard GIS package having the ability to use real time data added in. The server is more a facility to receive data requests from the client machine and locate and deliver the required data to the client in real time. The key part of this technology is that the GIS package must be Internet-aware, which means that the GIS program on the client side can read remote data as it does on a local disk and can understand data of various formats. To read remote data as a local disk does, protocols such as Network File System (NFS) for UNIX systems and distributed File System (dFS) for Windows systems need to be followed. Enabling the communication between different data formats is within the working goal of some organizations, including Open GIS. A further-empowered model will need more functions on both client and server side, which will probably request better communication among elements of the whole system. Common object request broker architecture (CORBA) can be introduced into the system to enhance communication, although progress in this area is limited.

Although the CIAA Internet GIS application is the highest and most powerful solution, some related technologies still warrant further exploration. Moreover, the requirements on the client side for both hardware/software and GIS expertise are strict. An efficient system is necessary to provide timely knowledge of data locator and transfer server about the location, maintenance, and availability of multiple data sources.

Conclusion and Discussion

The Internet is a good vehicle for implementing the combination of distributed computing technology with traditional GIS technology. Internet GIS, being a solution that can provide easy access to both information and GIS functions and allow various parties to share information and resources efficiently, is a valuable tool for enhancing health service access analysis so as to improve our health service delivery system. The three architectures proposed in this paper represent three basic solutions for employing Internet GIS in health service access analysis. They differ in that each solution is designed to satisfy different user needs and project objectives. For the majority of people who are more interested in getting general health service information such as locations, directions, and basic service categories, SAQD Internet GIS is efficient and effective enough. For users who are concerned about more details of the location factors and access situation of certain health service sites, IAIQ Internet GIS can provide more powerful service. This architecture, though, requires a relatively more powerful client machine as well as more patience and knowledge from the user in order to download

the GIS tool kit and to formulate queries. CIAA Internet GIS is the highest level and most powerful solution, which is sufficient for health service analysts, planners, development policy and strategy stipulators, and other public health organizations and agencies to analyze, plan, and evaluate the access situation of health service sites. Generally speaking, the more powerful the solution, the more resources both technically and financially are involved, and the more requirements are put on users for their special skills and techniques. As to which solution is the best, it depends on the specific situation of the project in terms of major users, available resources, and the main purpose of implementing the project.

As mentioned, some technical parts for CIAA Internet GIS are still immature. Actually, most efforts so far in trying to link traditional GIS with the Internet and distributed computing technology are in the experimental stage of developing both prototype and production service. Nevertheless, the development of Internet GIS will definitely benefit analysis of health service access greatly.

There are many other problems awaiting a solution before a real time Internet GIS is implemented. These problems could be institutional (both intra-institutional and inter-institutional), financial (investment for project development), and ethical and legal (data privacy and information accountability). But it is quite sure that by helping people from various social, economic, and cultural strata in their ability to access and process spatial information, Internet GIS could be an efficient way to alleviate the potential polarization between the information rich and poor in the coming information society (6).

Acknowledgments

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